Ionizing Radiation Notes

Ionizing radiation does not need to be feared if it is understood. The purpose of this presentation is to address the characteristics of ionizing radiation.

Slide 4 – ionizing vs non-ionizing radiation

- all electrical devices (lights, TVs, microwave ovens, cell phones, electrical transformers, high-voltage transmission lines, etc.) emit only non-ionizing radiation
- no evidence that non-ionizing radiation exposure causes cancer

Slide 5 – electromagnetic spectrum

- non-ionizing up to low-energy ultraviolet
  - — includes visible frequencies and frequencies of all electrical and electronic devices
- high-energy ultraviolet to cosmic radiation is ionizing

Slide 7 – alpha particle radiation

- alpha decay governed by strong nuclear and electromagnetic forces, in which particle with two neutrons and two protons ejected from nucleus of radioactive atom; particle identical to nucleus of helium atom
- alpha decay occurs in very heavy elements such as uranium, thorium and radium
- two protons give alpha particle positive charge of two
- particle very heavy and very energetic compared beta particle (electron) radiation
- particle interacts readily with materials, including air, causing many ionizations in very short distance; typically travel no more than few centimeters in air and stopped by sheet of paper

Slide 8 – beta particle radiation

- beta decay governed by weak nuclear force, in which neutron in atomic nucleus converted into proton and electron; proton stays in nucleus, but electron ejected along with unusual particle called antineutrino
- because electron originates in atomic nucleus, is called beta particle to distinguish it from electrons that orbit atomic nucleus
- beta particle has single negative charge and weighs only small fraction of neutron or proton
- interacts less readily with material than alpha particles; travels up to several meters in air (depending on particle’s energy) and stopped by thin layers of metal or plastic

Slide 9 – gamma-ray radiation

- interacts with matter by colliding with electrons in atoms

- range up to hundreds of meters in air and penetrates human body

Slide 10 – example gamma-ray emission following radioactive decay

- Co-60 decay scheme illustrates two beta decay modes to obtain Ni-60 nucleus
- excess energy of excited daughter nucleus (Ni-60) removed by emission of electromagnetic wave (gamma-ray) having no mass and no charge

Slide 11 – quantifying radioactivity

- as atoms decay, number of atoms of radioisotope decreases with time so activity also decreases with time

Slide 14 – penetrating properties of ionizing radiation

- low energy x-rays and gamma-rays blocked by dense materials like lead
- large thicknesses of lead required to block high energy gamma-rays

Slide 15 – LET graphic

- graphic illustrates contrast in frequency of radiation interactions with matter in given distance for low LET and high LET radiation
- high LET radiation more damaging because it deposits more energy over same path length

Slide 16 – relative relationship of radiation range to LET

- due to loss of only small amounts of energy in each collision, range of beta particles and gamma-rays in matter relatively large by time all energy lost in collisions
- alpha particles lose lot of energy in each collision and have relatively short range in matter
- alpha particles from external radiation sources have insufficient range and penetrating power to produce whole-body radiation dose

Slide 17 – alpha and beta particle ranges in air

- high LET alpha particles have very limited range in air
- range of low LET beta particles in air dependent on beta particle energy
- MeV – million electron volts, measure of energy

Slide 18 – external vs internal radiation exposure

- alpha and beta radiation not external radiation hazards – can’t penetrate dead layer of human skin
- gamma- and x-rays <u>potential</u> external health hazards; actual hazard dependent on source strength

Slide 20 – sources of natural background radiation

- pie chart shows various contributors to (chronic) natural background radiation dose
- note that although generally included as source of natural background radiation, medical radiation not chronic exposure as are other sources in pie chart
  - while medical radiation exposures vary widely in U.S. population, 53 mrem likely an average heavily weighted by people with serious health conditions
  - for perspective, annual dental x-ray radiation dose less than 1 mrem
- largest single contributor to natural background radiation dose is radon, which comes from radioactive decay of uranium and thorium – both very plentiful in Earth's crust
- cosmic radiation – high energy, heavy, charged particles entering Earth's atmosphere from sources in space
- cosmogenic radiation – secondary radiation resulting from cosmic radiation interactions with atoms in Earth's atmosphere

Slide 23 – absorbed dose

- historically x- and gamma-ray radiation measured in roentgens (R) – energy deposited in 1 gram of air
  - not useful for comparing effects of radiation in other materials
- now measured in rads (radiation absorbed dose) – energy deposition per unit mass of material
  - applies to all radiations and materials, and generally used to measure radiation energy deposited in biological systems
- since about 1980, accepted standard unit for absorbed dose is Gray

Slide 24 – radiation biological effectiveness

- in past, biological effects quantified using Quality Factor
  - Quality Factor of 1 chosen for low LET radiation and factor of 20 chosen for alpha radiation to characterize difference in adverse biological effects
- more recently, use of Quality Factors criticized for not accurately characterizing actual biological effects
  - tissue weighting factors proposed as more appropriate for calculating dose; dose then dependent on specific biological tissue being exposed

Slide 28 – acute exposures in perspective

- note logarithmic scale and dose in microgray so that order-of-magnitude differences between normal low-dose exposures and high-dose threshold for harm are obvious
- public acute radiation exposures are external exposures to low LET radiation since high LET radiation (i.e., alpha particles) cannot penetrate clothing or dead layer of human skin

- note that average U.S. daily exposure from natural background radiation not acute exposure, but shown merely for comparison purposes

Slide 29 – chronic exposures in perspective

- note logarithmic scale and dose-rates in microgray per hour so that order-of-magnitude differences between normal low-dose-rate exposures and high-dose-rate threshold are obvious
- public chronic radiation exposures include both external exposures (i.e., natural background radiation) and internal exposures (from inhaled radon and natural radioactivity in the human body)
- longevity most important health effect of chronic radiation exposure
- high-dose-rate threshold for low LET radiation about 80 μGy per hour; that is, threshold dose-rate with potential to result in lifespan shortening
  - U.S. average chronic exposure from low LET natural background radiation around 0.12 μGy per hour
- 1 μGy per hour conservative high-dose-rate threshold for internal high LET radiation with potential to result in lifespan shortening
  - some inhabitants of Ramsar, Iran receive exposures as high as 1 μGy per hour (due to high concentrations of radon) with no evidence of lifespan shortening
  - radon constitutes ≈ 55% of U.S. average natural background radiation exposure producing dose-rate of 0.01 μGy per hour